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Is a peaceful cohabitation between living species possible? An empirical analysis on the drivers of threatened species

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Abstract

Some scientific views argue that human population and economic activities might be expanding at the cost of other biological species. Hence, this paper proposes an empirical analysis on the case of threatened animal and plant species, exploiting an international panel dataset to test whether there is a peaceful cohabitation with human activities. Applying count data regression techniques we show, on the one hand, that human population growth and agricultural production harm animal and plant species. On the other hand, our results indicate that the number of threatened animal and plant species depicts an inverted U-shaped curve with income per capita. Our analysis further suggests that the more biological species-rich a region is, the more threatened species it holds, other things being equal. Globally compared to developing countries, developed countries definitely appear to be threatening fewer animal and plant species, suggesting a possible peaceful cohabitation between living species.

Keywords: Biodiversity loss, threatened species, income, population, control function approach

JEL Classification: C23, C29, Q57.

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1. Introduction

Reversing the trend of the ongoing extinction of biological species is a challenging environmental issue faced by human societies. On the behalf of the wide range of ecologists, Polasky et al. (2005) claimed that "we may now be witnessing the sixth great extinction wave on the planet". Regarding the amplitude of the threat to biodiversity, data from the International Union for Conservation of Nature (IUCN's Red-List) indicate that out of 100 species identified circa 39 are threatened by extinction. Furthermore, the evolution of the *Living Planet Index* (LPI) in the last 50 years globally shows a drastic declining trend. Discussing why biodiversity loss is a serious issue, the Millennium Ecosystem Assessment's report (2005), the IUCN and the Convention on Biological Diversity (CBD) all agree that human societies are built and rely on biodiversity. Hence, biodiversity loss threatens human well-being. On this, International organizations and scientists seem unanimous on this that changes in the abundance and distribution of species may have serious consequences for human societies. In order to find possible solutions to environmental degradation and biodiversity loss, it becomes important to identify the determinants of species extinction and further to question the role of human species.

On the topic, works among others by Grossman and Krueger (1993, 1995), John and Pecchenino (1997), Koop and Tole (1999), Nunes et al. (2001), Panayotou (2000, 2003), Azomahou et al. (2006, 2016), Brock and Taylor (2010), Dasgupta (2010), Katz (2015) and Poufoun et al. (2016) contributed to the analysis of environmental issues, working on indicators such as gas emissions, deforestation, water use but also on valuing biodiversity and biological species loss. The latter, strongly tied to ecosystem services, has received less attention in the economic literature, in comparison to pollutants concentration. Nevertheless, in the recent economic literature, researchers have started focusing on the particular topic of biodiversity loss theoretically as well as empirically.

Theoretical works addressing the issue of species loss as results of economic activities and human population growth seem few in comparison to the debate on gas emission. Still, these few existing theoretical approaches have given birth to the economics of biodiversity, permitting an understanding of how economic and human activities affect natural resources and biodiversity. Tisdell (2011) argued that aggregate economic activities are the main cause of biodiversity while Lanz et al. (2018) point to intensive agriculture. Likewise, Cabo (1999), Polasky et al. (2002) and Alam and Quyen (2007) proposed very comparable North-South models that reveal the effects of international trade on biodiversity. Specifically, as introduced by Flam and Helpman (1987) and Copeland and Kotwal (1996), Alam and Quyen (2007) in a general equilibrium model assuming the South to be rich in forest land outlined how an unsustainable population growth in the South may have the same effects on biodiversity as openness to trade.[1] Similar contributions to this literature led by Rosen et al. (1994), Farrow (1995), Carlos and Lewis (1999), and Taylor (2011) have been focused on the extinction of specific species. Using economic models to explain species loss and ecosystem depletion as done by these authors is not without precedent. It actually can be traced back to the 1950s and even earlier. Gerhardsen (1952) and Scott (1954) followed by Schaefer (1957), Clark (1773, 1974) and Huang and Lee (1976), to cite few, have been some of the first authors to analyze fish and mammal species exploitation in economic frameworks. In a more recent literature, the question of resources depletion has become whether nature will always be able to support human societies, as the excessive demand on natural resources leads to pollution, deforestation and biodiversity loss. This biologist and neo-Malthusian viewpoint is analyzed in economic models by Smith (1975), Brown (1995), Brander and Taylor (1998), among others. For this group of researchers, resources depletion and biodiversity loss threaten human well-being and will probably lead human societies to disastrous consequences.

Regarding empirical studies, the drivers of species extinction and mainly the existence of an Environmental Kuznets Curve, henceforth EKC, for threatened species have been a central research topic. The EKC-hypothesis states that in the process of economic development, the environment depletion tends to increase until a certain level in income per capita after which it decreases, depicting an inverted U-shaped curve. Thus, on biodiversity loss, significant contributions have been made by researchers such as Asafu-Adjaye (2003), Freytag et al. (2012), Carter et al. (2015) and Polaina et al. (2015). Despite the Fuentes' (2011) argument for the absence of conflicts between economic growth and biodiversity, strong empirical results based on a wide range of biodiversity indicators suggest that human population dynamics, cities en-

[1]The main idea was that having a comparative advantage in producing agricultural goods, the openness to trade may impel the South to clear its forest in order to satisfy the demand for agricultural goods in both South and North.

largement, and economic activities threaten biodiversity. Verboom et al. (2007) for instance projected a decline of biodiversity in the near future. For their part, Dietz and Adger (2003) and Mills and Waite (2009) using a species richness index, Hoffmann (2004) using a calculated endangering rate for mammal and bird species whereas Halkos and Tzeremes (2010) using a biodiversity performance measure, found results indicating that economic growth conflicts with biodiversity. Relying solely on the number of threatened species broadly classified into seven taxonomic groups, Kerr and Currie (1995), Naidoo and Adamowicz (2001), Majumder et al.(2006), Perrings and Halkos (2010), and Freytag et al. (2012), among others, provided results stating that economic growth harms biodiversity by increasing endangered species.[2]

It is important to mention that investigating an EKC for biodiversity is very delicate and it should be carefully treated. Indeed, contrary to the case of gas emissions where countries are supposed to be reducing their gas emissions after a certain level of income, biodiversity cannot be as easily reconstituted once species are extinct. Contrariwise, focusing on threatened species such an investigation is feasible, since the indicators are stocks of endangered animal and plant species. Nonetheless, the results should be thoughtfully interpreted. Regarding the case of threatened species, the previous empirical papers do not permit to claim an EKC which is consistent with sustainability.

In this paper we propose an empirical investigation on the determinants of biological species lost, using as biodiversity indicator the total counts of *critically endangered, endangered* and *vulnerable* animal and plant species. Three main considerations guide that focus. First, accounting for the number of threatened animal and plant species may help find out the main drivers of biodiversity loss in high and low-income countries. Second, it permits investigating whether a harmonious cohabitation is possible between animal and plant species and human activities. Finally, to the best of our knowledge, there are few empirical research papers on the topic and even more on the case of plant species. Aiming to fill that gap, this paper contributes to the literature on the determinants of biodiversity loss and further on the economic growth-biodiversity nexus for threatened species. However, considering globally animal and plant species may hide some taxonomic realities.[3] Still, it has the advantage of providing an

[2] It is to signal here that these results by Perrings and Halkos (2010) in "Biodiversity loss and income growth in poor countries: the evidence" are reported in Perrings (2010, pp:15-17)

[3] Realities such as the real level of the threat in each group, birds, amphibians, and mammals are hidden.

aggregate indicator concerning the global state of the threat to biological diversity. Regarding our econometric model, it matches the nature of the data in explaining the number of threatened animal and plant species by income per capita, population dynamics and other determinants. We further control for endogeneity bias by relying on a control function approach to find results suggesting that a harmonious cohabitation between economic growth and biological species diversity is possible.[4]

This paper is organized as follows. In Section 2, we describe the data employed in the empirical analysis with a particular attention given to series on threatened species. Section 3 comprehensively describes the method we use in estimating the parameter of a regression model relating the number of threatened species to its determinants. Section 4 exposes the results of our empirical analysis. In Section 5, we check our results for robustness and Section 6 draws some conclusions.

2. Data and variables

2.1. The main series

Investigating the main sources of biodiversity loss, this paper exploits count data on total animal and plant species classified by the IUCN Red List as being threatened by extinction. More precisely, these are species qualified as vulnerable, endangered and critically endangered, since facing an extremely high risk of extinction.[5]

Among the threats to biodiversity, the UICN listed habitat disturbances and loss, overexploitation, pollution and climate change. Consequently, to capture human activities similarly to the existing literature, we use GDP per capita evaluated in purchasing power parity (PPP, in 2011 $), population density, and series on trade, industry and on agriculture added values (in % of GDP). Further control variables such as the mean years of schooling, the share of forest land, foreign direct investments and climate zones are also included in our dataset. Our data cover the period between 2007-2014 and include 179 developed and developing countries with highly different income level.

[4]The endogeneity bias would flaw results, it was not appropriately tackled.

[5]For more details on these three subcategories, see the IUCN Key Documents on the categories and the classification criteria. For further criteria and for a summary of the 5 criteria (A-E) used to evaluate whether a taxon belongs in an IUCN's red list of threatened category (critically endangered, endangered or vulnerable)

Table 1: Descriptive statistics

Variables	Units	Mean	S.D.	Min.	Max.	Obs.
lnGDP per capita	\$, PPP 2011	9.10	1.24	6.34	11.82	1210
Threatened plant species	Number	51.86	111.07	0	1839	1232
Total plant species	Number	151.88	199.29	21	2542	1232
Threatened animal species	Number	123.39	147.45	5	1009	1253
Total animal species	Number	1131.61	929.15	18	5733	1253
Agriculture, added value	% GDP	13.31	12.65	0	58.21	1103
Industry, added value	% GDP	28.52	13.06	4.00	78.20	1110
Mean years of education	Number of years	7.77	3.20	0.00	12.90	1055
Foreign direct investment	% GDP	5.586	11.910	-43.463	255.423	1253
Trade openness	% GDP	92.76	53.45	19.45	455.42	1183
Forest area	% of area	32.54	23.88	0.00	98.46	1061
Rents of natural resources	% of GDP	2.57	5.19	0.00	43.85	1011
Population density	$1000/km^2$	0.32	1.55	$1.69e-3$	19.07	1235
Agricultural land	% of land area	40.291	21.69	0.453	84.642	1253
Gross fixed capital formation	% GDP	20.498	9.005	1.560	73.663	1253
Control for corruption	Index	-0.08	0.99	-1.92	2.52	1253

Notes: Number of countries = 179; period: 2008-2014; number of observations: 1253.

Observing Table 1, one notices that the standard deviation (S.D.) of trade and the series on animal and plant species, takes high values, indicating a heterogeneous character of the considered sample.[6] The highest levels in GDP per capita are observed in Macau, Qatar, and Luxembourg. Regarding threatened animal and plant species, the highest values are observed in the USA and in Ecuador; the fastest population growth rates are observed in Qatar (2008-2010) and Oman (2010-2013). By focusing only on income and the number of threatened species, it is to say that high-income countries seem to show relatively less threatened species. In addition to these variables, our dataset includes an indicator of corruption and level of education. The former is considered to be reflecting the institutional quality of countries whereas the latter broadly traduces the average country-level of schooling, hence human capital at the country level.

2.2. Data on threatened species

Eppink et al. (2007) and Bartkowski et al. (2015) discussed the complexity and the multi-dimensionality of the concept of biological diversity which justifies the existence of several proxies. Using counts of threatened species as biodiversity indicators, Hoffmann (2004) and Cunningham and Lindenmayer (2005) among others pointed out they have non-standard features and create some statistical challenges. This is because the key distributional assumptions (normality and homoscedasticity) are not fulfilled for applying standard linear modeling techniques. Aiming here to use the number of threatened animal and plant species, it is important to have insight into the count data. Thus, in addition to the descriptive statistics, we propose a histogram of our series on threatened animal and plant species which provides details regarding the symmetry or skewness of the distribution.

Both histograms, Figure 1, indicate that the series on our response variables are not symmetrically distributed but are rather right-skewed. To model such series, one should consider some appropriate econometric techniques.

[6] The series on trade are obtained computing the share of exportations and importations in GDP

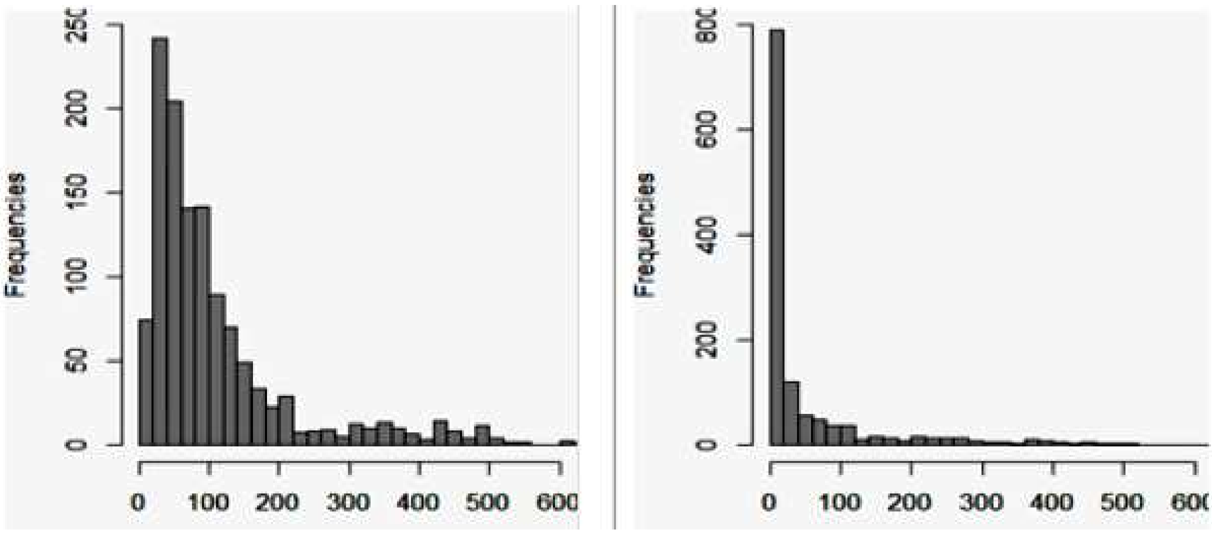

Figure 1: Histogram of counts on threatened animal and plant species

3. Econometric model

To test the role of economic activities and further factors in threatening animal and plant species, we mainly use parametric count data regression methods. Prior to that, we propose a non-conditional and non-parametric regression, carrying out the functional form of the link between the number of threatened animal and plant species and income per capita.

Exploring count data, the econometric literature, e.g. Cameron and Trivedi (1998, 2013), Hilbe (2011) and Winkelmann (2008), usually argues for the use of Poisson-Gamma mixture models. Considering the number of threatened species, y_{it}, to be Poisson distributed, $f(y|x) = \frac{e^{-\mu}\mu^y}{y!}$, and assuming independence between the vector of exploratory variables, x_{it}, and the error term, ε_{it}, we start from the following model passing over individual time variabilities.[7]

$$\mu_{it} \equiv E\left[y_{it}|x_{it}\right] = \exp(x'_{it}\beta) = \exp(x'_{it}\beta),\ i = 0, 1, \cdots n,\ t = 0, 1, \cdots T, \tag{1}$$

The regression model (1) suffers from two major issues. First, Table 1 shows patterns of overdispersion in the series on threatened animal and plant species. A Negative Binomial distribution releasing the mean-variance equality assumption should be considered. Second, the model assumes independence between the unobserved errors ε_{it} and the regressors x_{it}. The set of explanatory variables includes GDP per capita, agricultural and industrial value-added which seem endogenous since economic production activities can be reversely explained by exploitations of natural resources and biodiversity. These endogeneity issues can lead to biased estimation (Cameron and Trivedi (2013)). A very straightforward and novel way to deal with that issue is the so-called control function approach (CFA) for non-linear models discussed in Winkelmann (2008) and Wooldridge (2014, 2015a).

Assuming now x_1 to be an endogenous regressor, GDP per capita for instance, and also a valid instrument, Z_1, the CFA proposes a first stage regression whose residuals are introduced back into the conditional mean equation at the second stage estimation. The first stage regression is:

[7]Our dataset having a very small T, associated with low time-variability in the response variable for a relatively high number of individuals (n=179), we ignore the individual effects, assuming homogeneity of the slope coefficients over time. Econometric test, Baltagi and Griffin (1997,) Pesaran and Smith (1995), and Baltagi et al. (2008), indicates that in panel data with T very small, traditional homogeneous estimators would appear the only viable choice.

$$x_1 = \rho Z_1 + x'\delta + v, \text{ where } v|x, Z \sim N(0, \sigma^2 I). \tag{2}$$

The second stage regression considers the conditional mean (1) augmented by $\hat{v}_{it} \equiv x_1 - \hat{\rho} Z_1 - x'\hat{\delta}$, which is viewed as a new explanatory variable:

$$\mu_{it} \equiv E\left[y_{it}|x_{it}, x_{1,it}\right] = exp(x'_{it}\beta + \beta_1 x_{1,it} + \beta_v \hat{v}_{it}) \tag{3}$$

Wooldridge (2015a) mentions that introducing the first stage residuals in equation (3) controls for the endogeneity of x_1. Moreover, it serves the purpose of producing a heteroskedasticity-robust endogeneity test.[8] Relying on this control function approach in count data models, the parameters vector β and β_1 can be estimated using maximum likelihood.

4. Estimation results and discussion

4.1. Tests for overdispersion

Before estimating the parameters of regression models relating the number of threatened species to income per capita and other determinants, it seems important to run overdispersion tests which help find out the true distribution of our series of threatened species. Testing for overdispersion is equivalent to test the mean-variance equality assumption of the Poisson distribution, as huge differences are observed between the mean and the variance of the series on threatened animal and plant species (Table 1). Dean and Lawless (1989) proposed a Z-score test which seems straightforward to implement. Applying this test to our different model specifications, we find results suggesting the existence of overdispersion in the series on threatened species. Tables 2 & 3 summarize tests results indicating that modeling the number of threatened animal and plant species, overdispersion should be accounted for.

4.2. The income and threatened species nexus

As parametric specifications could be misleading in investigating the shape of complex relationship, the following proposes a prior non-parametric analysis uniquely focused on the relationship between GDP per capita and the number of threatened animal and plant species. The Nadayara-Watson or local constant kernel estimator of a univariate model seems to be

[8] The null-hypothesis H_0: $\beta_v = 0$, yields the explanatory variable is actually exogenous. See also Wooldridge (2014)

a suitable procedure, as it does not impose any functional form for GDP per capita.

Variance stabilizing transformations for regression models in exponential families are often used to modify the data, making non-parametric regression procedures easily feasible (Brown et al. 2010). Main contributions on the topic are made by Anscombe (1948), Hoyle (1973), Efron (1982), and Brown et al. (2010) in the statistical literature on count data transformations. In the literature on threatened species, Dietz and Adger (2003) and Mills and Waite (2009) divided the number of species by the country size, Hoffmannn (2004) by the total number of species accessed whereas Perrings and Halkos (2010) used a log-transformation. Following this literature, we modify our count data using $\ln(y_{it} + k)$ operator as proposed by Anscombe, with $0 \leq k \leq 1$.[9] Thereby, the NB mean-variance relation, $\sigma^2 = \mu + \frac{1}{k}\mu^2$, is used to compute k. Exploiting the log-transformed counts, the Nadayara-Watson estimator is applied to the regression of $\ln(y_{it} + \hat{k})$ on income per capita, x_{it} and this using different samples of our dataset.

The main objective is to estimate the regression function $m(x) \equiv E[\ln(y_{it} + \hat{k}|x_{it})]$ directly. Moreover, since the EKC hypothesis stipulates that environmental depletion tends to slow down after a certain level of income per capita, using for response variable time-averaged counts and even log-modified counts should permit to validly investigate the income and threatened species nexus. The global level results of the local constant kernel estimator are displayed in Figure 2 below for both animal and plant species.

[9] Lambert et al. (2010) and Cameron and Trivedi (1998) proposed different approaches in estimating k.

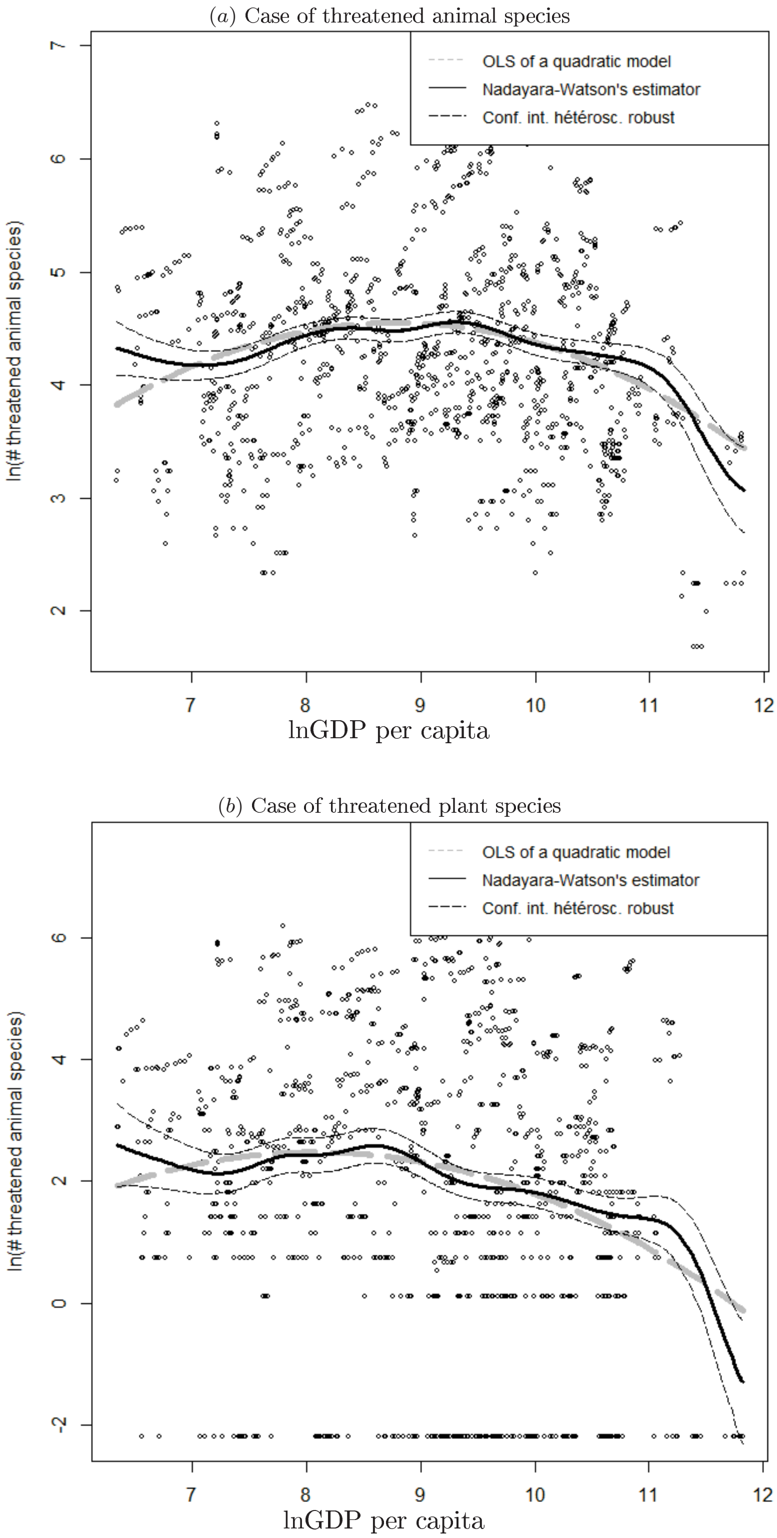

Figure 2: Non-parametric model of log-modified count on threatened animal and plant species and lnGDP per capita. The black curves are the NW estimator and its 95% confidence interval. The gray curve corresponds to the OLS regression of the parametric counterpart, ie the quadratic model.

On the case of animal species, Figure 2 shows a slight upward trend in the number of threatened species for low-income levels. This trend becomes downward after a certain level in log-income per capita, the turning point being around the mean of the sample. Hence, in low-income countries, there is a positive link between income and threatened animal species while the results point to a negative one in high-income countries, confirming theoretical predictions of an EKC. Regarding threatened plant species, the regression-line shows patterns similar to the results obtained while considering animal species. Considering low-income levels, no fair conclusion can be made, as the confidence interval is quite large. After the sample mean of log-income per capita, circa 9.10 USD, the results are analogous to those obtained in the case of animal species, suggesting that in high-income countries, economic activities do not conflict with plant species.

Distinguishing regional entities, Africa, America, Asia, and Europe, some clear heterogeneities appear on the relationship between the number of threatened animal and plant species and income per capita. In Africa and America, conflicting upward trends can be identified, while in Asia and Europe inverted U-shaped links occurs between the number of threatened species and income per capita.

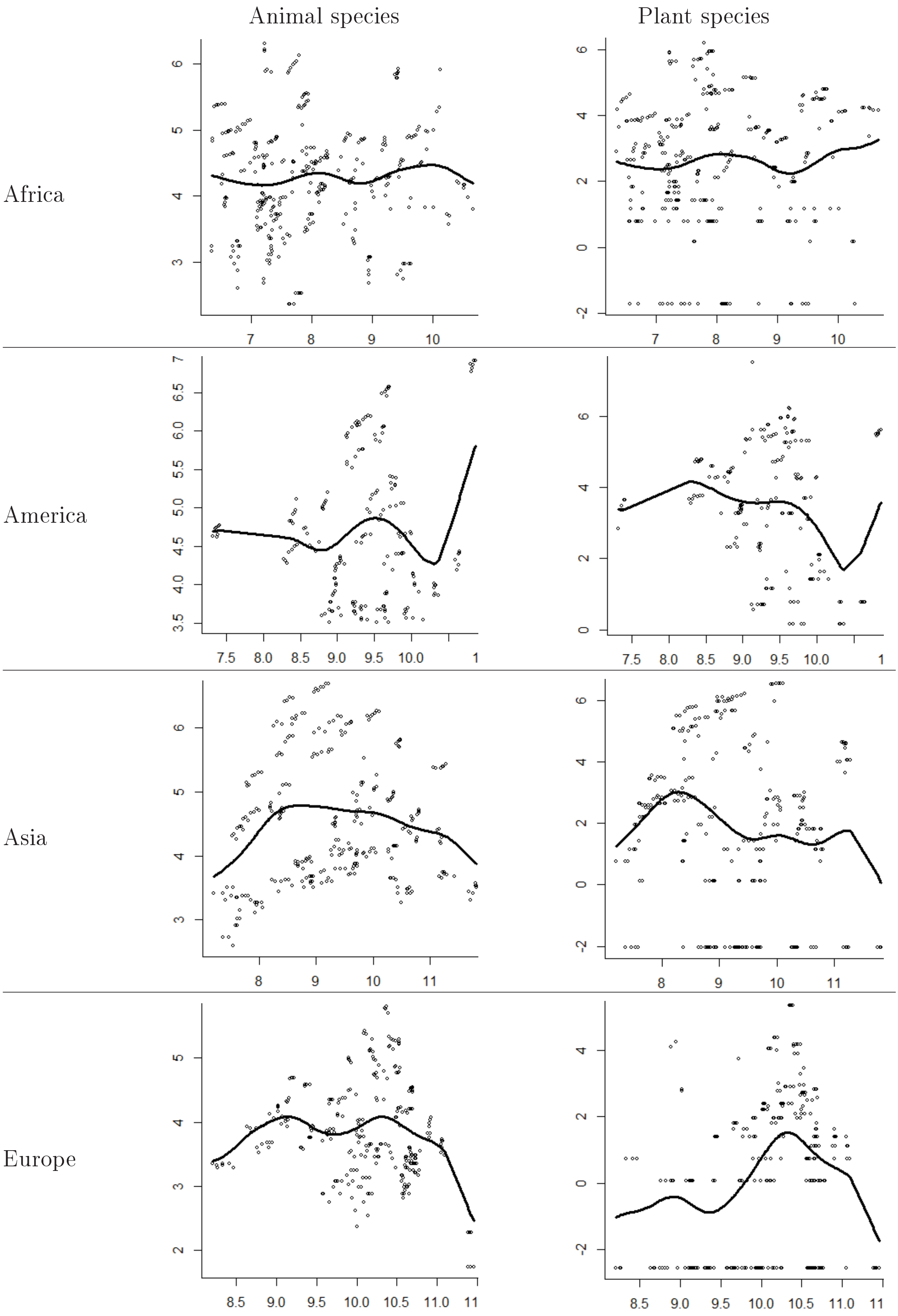

Figure 4: Regional heterogeneities: Scatter plot and smoothing regression line

4.3. Determinants of biodiversity loss and regional heterogeneities

4.3.1. Determinants of biodiversity loss

Considering the counts of threatened animal and plant species to be NB distributed, the econometric literature indicates that NB estimates are asymptotically normal, efficient and unbiased. However, this unbiasedness is violated in presence of endogeneity issues. Estimating the parameters of the different model specifications, we address the endogeneity issues by exploiting the CFA (Wooldridge (2014, 2015a)) discussed above. Thereby, as instrument for GDP per capita, agriculture and industry value added, we respectively use the index on control for corruption, the share agricultural land in surface area, and the share of gross fixed capital formation in GDP.

Table 2 reports the results of estimating the parameters of four different NB model specifications considering threatened animal species. Observing models 1 and 2, one notices that using a linear specification in explaining the number of threatened animal by income per capita does not provide conclusive results in comparison to a quadratic one. Furthermore, by comparing the information criteria of the different specifications, model 4 shows larger predictive power and therefore will be mainly considered when analyzing the determinants of biological species loss.

Our results indicate that human activities are not neutral in threatening biodiversity, as income per capita, FDI, and industry added value significantly affect the number of threatened animal species. More precisely, our results reveal a non-linear relationship between income per capita and threatened animal species implying that economic activities increasingly threaten biodiversity in low-income countries, while it decreasingly does in high-income countries. Such a result, known in the empirical literature as the presence of an EKC relationship, seems to hold as the sign of the parameters of both income per capita and its quadratic form remains unchanged throughout the different specifications. Moreover, the estimated parameters remain statistically significant when several factors are controlled for. Though parametric model specification could be misleading, such a result supports the conclusions from Figure 2 on the existence of an inverted U-shaped relationship between income per capita and the counts of threatened animal species.

Table 2: Animal species: Estimation results of negative binomial models

Covariates / Models	Model 1	Model 2	Model 3	Model 4
Intercept	5.125^{***} (.429)	-1.871 (1.533)	.915 (1.479)	1.421 (1.522)
lnGDP per capita	$-.034$ (.048)	1.494^{***} (.348)	$.706^{**}$ (.319)	$.532^{*}$ (.316)
Squared lnGDP per capita		$-.082^{***}$ (.019)	$-.036^{**}$ (.016)	$-.032^{**}$ (.016)
Total animal species			$.640^{***}$ (.030)	$.525^{***}$ (.053)
Climate zone			$-.010^{***}$ (.002)	$-.015^{**}$ (.006)
Forest area			.001 (.001)	.000 (.002)
Mean years of schooling			$-.020^{***}$ (.006)	$-.018^{**}$ (.007)
Rents of natural resources			$-.006^{***}$ (.001)	$-.045^{**}$ (.014)
Foreign direct investment				.007 (.004)
Agriculture, value added				.003 (.011)
Industry, value added				.059 (.037)
Trade				$-.006^{*}$ (.001)
Population density				$.045^{**}$ (.018)
$\hat{v}_{Industry\text{, v.a.}}$				$-.069^{***}$ (.019)
$\hat{v}_{Agriculture\text{, v.a.}}$				$-.022^{*}$ (.010)
$\hat{v}_{GDP\text{ p.c.}}$	$.146^{***}$(.053)	.026 (.049)	.054 (.054)	$.172^{**}$ (.055)
Number of obs.	1210	1210	969	831
AIC criterion	14059	14044	10278	8675
Log likelihood	-7025.521	-7017.044	-5129.119	-4320.489
Tests for overdispersion				
Z-score test	124.860	125.190	33.57	30.705
P-value	$<$2e-16	$<$2e-16	2.22e-08	1.19e-09

Note: Dependent variable is the counts of threatened animal species. Robust standard errors in brackets. Unbalanced panel data, with n=179 and T=7. "***", "**" and "*" respectively stand for significance level at 1, 5 and %. Regarding the overdispersion tests, the null hypothesis is equidispersion.

Besides this, our results indicate that trade and the rents of natural resources (mainly oil, natural gas, coal and mineral rents) do not harm animal species. Controlling for species richness and climate by using the total number of animal species identified and the distance from equator indicates that more threatened animal species lie in species-rich regions while less are found in countries far from the equator. These results imply that in tropical zones where biodiversity mostly lies, relatively high species are threatened by extinction.

With regard to the theoretical results by Polasky et al. (2002) and by Alam and Quyen (2007)[10], our regression model controls for forest share in surface area, trade and for agricultural production by using its added value in GDP. The size of forest in a country seems neutral for threatened animal species. Regarding trade and agricultural production, our results contrarily to Alam and Quyen (2007) globally imply that agriculture and openness to trade are not to blame for threatening animal species. Further interesting results on the case of animal species are the role of human population density and education. Approximating education by the mean years of schooling, the estimates suggest that a high level of education helps significantly reduce the number of animal species at threat. Since countries with higher levels of education are also those showing high incomes in addition for being non-tropical countries, such a result seems not surprising but rather corroborates guesses of decreasing link between the counts of threatened animal species in high income countries and education. Population density however is positively linked to the number of species at threat, meaning that the more human population grows the more threatened animal species there are. Such as result points out the existence of a possible competitive exclusion between human population and animal species.

On the case of plant species, our regression analysis follows the same methodological approaches and uses the same specification and instrumental variables as above. Hence, Table 3 presents the results of NB model for threatened plant species exploiting the control function strategy, in solving for endogeneity issues related to the presence of GDP per capita, agriculture and industry added values among the regressors.

[10] The main results sustain that the openness to international trade and increases in demand for agricultural goods may lead to deforestation and species lost in the south.

Table 3: Plant species: Estimation of negative binomial models

Covariates / Models	Model 1	Model 2	Model 3	Model 4
Intercept	8.808*** (.489)	−3.247 (2.428)	−7.730** (3.299)	−10.980** (4.614)
lnGDP per capita	−.542*** (.053)	2.063*** (.552)	2.414*** (.750)	2.067** (.884)
Squared lnGDP per capita		−.138*** (.031)	−.134** (.043)	−.116** (.044)
Total plant species			5.198*** (.000)	5.580*** (.001)
Climate zone			−.036*** (.007)	.020 (.012)
Forest area			.009*** (.002)	.030*** (.006)
Mean years of schooling			.028 (.027)	−.042* (.020)
Rents of natural resources			−.008** (.003)	−.034 (.056)
Foreign direct investment				.009 (.013)
Agriculture, value added				.142*** (.039)
Industry, value added				.064 (.085)
Trade				−.009*** (.003)
Population density				2.183*** (.556)
$\hat{v}_{Industry,\text{ v.a.}}$				−.054 (.077)
$\hat{v}_{Agriculture,\text{ v.a.}}$				−.162*** (.033)
$\hat{v}_{GDP\text{ p.c.}}$	.868*** (.069)	.621*** (.061)	.015 (.138)	.122 (.132)
Number of obs.	1190	1190	955	822
AIC Criterion	10483	10473	7785.7	6609.8
Log Likelihood	-5237.518	-5231.509	-3882.855	-3287.886
Tests for overdispersion				
Z-score test	154.510	146.110	61.226	51.072
P-value	5.98e-07	5.38e-08	2.19e-10	2.68e-10

Note: Dependent variable is the counts of threatened plant species. See Table 2 for further comments.

Explaining uniquely the number of threatened plant species by income per capita (Model 1) gives first hints on an overall declining link between both factors, indicating that the threat to plant species tends to decrease with the development level. Considering larger models including income per capita, its quadratic form and further determinants, Model 4, rather suggests an inverted U-shaped relationship between the number of threatened plant species and income per capita, as GDP per capita appears to be positively related to the response variable, whilst its squared form shows a negative link. Similarly to the case of animal species, when considering the number of species identified and the climate zone, the estimations show the same results revealing that more threatened plant species are found in tropical and species-rich countries. Human capital measured here by mean years of educations attainment also appears to be reducing the number of threatened plant species. As well, the openness to trade and the exploitation of natural resources are not to blame for threatening plant species.

Further, production in the agricultural sector measured by its added value in GDP threatens plant species, as the estimated parameter is positive and significant. Production in agricultural sector requiring land, such a result denoting conflicts between plant species and agricultural production is understandable. Regarding human population dynamics captured here by population density, it is positively and significantly linked to income per capita, supporting our conclusion regarding possible competitive exclusion or conflicts between human population and other biological species. Further, the positive and significant effects of forest observed here likely implies that the larger forest share a country has, the more plant species rich there are, and consequently the more threatened plant species it shelters.

4.3.2. Regional heterogeneities

Investigating possible heterogeneities, this regional analyses exploit the same data as above but classified by continent. Tables 4 and 5 present the results of estimating Model 4 continent by continent. Thereby, we also use control functions in solving for potential endogeneity biases.

• Africa: The number of threatened animal and plant species depicts a U-shape relationship with income per capita. Being mostly in tropical zones and largely covered by forest, African countries rich in animal and plant species are consequently those sheltering relatively high numbers of species threatened by extinction. Besides, economic activities in agriculture and population dynamics are found to be increasing the number of threatened species. Based on these results, there seems to be a conflicting cohabitation between human activities and biological species in Africa.

- America: A non-linear and seemingly U-shape link appears between the counts of threatened species and income per capita. Our results suggest that larger forest covered American countries show less threatened animal species contrarily to plant species, which also appear to be largely threatened by extinction in temperate climate zones. Moreover, there appear to be no conflicts between agricultural production, population density, and biological species, whereas natural resources exploitation, likely forest rents, threatens animal species.
- Asia: The estimation results suggest an inverted U-shaped curve between the number of threatened species and income per capita, similarly to those provided by the global-level analysis. In addition, species-rich, large forest covered and Asian tropical countries shelter more threatened animal and plant species. Also, agricultural sector and population density seem neutral in threatening biodiversity in Asia.
- Europe: Considering animal and plant species, the shape of the link to income differs. Regarding animal species, the result points to a seemingly inverted U-shaped, while a U-shaped relationship appears for plant species. Besides income, no further factor is found to be harming species diversity except educational level for plant species. The latter factor simply suggests that a large number of plant species are at threat in European countries with relatively high levels of education.

Separating countries according to income level provide a new perspective into the analysis of the determinants of biodiversity loss with respect to development level.

Table 4: Animal species: Estimation of negative binomial models

Covariates / Models	Africa	America	Asia	Europe	High-income	Low-income
Intercept	8.52 (4.842)	32.60***(7.647)	−7.21***(2.187)	21.66 (23.99)	−35.81***(7.172)	55.27***(21.945)
lnGDP per capita	−1.299* (.787)	−4.140***(1.633)	2.945***(.436)	2.619***(.991)	8.332***(1.360)	−1.503(1.303)
Squared lnGDP per capita	.058***(.054)	.188***(.086)	−.165***(.023)	−.123***(.049)	−.405***(.064)	.067(.072)
Total plant species	.679***(.112)	.379***(.061)	.505***(.063)	−4.484 (4.470)	.547***(.032)	15.449*** (5.997)
Climate zone	.135***(.042)	−.042***(.011)	−.026***(.005)	−.412 (.295)	−.026***(.003)	1.446** (.591)
Forest area	.031***(.010)	−.018***(.004)	.006***(.002)	−.072 (.061)	−.004**(.002)	.486*** (.196)
Mean years of schooling	−.075***(.031)	−.070***(.013)	−.057***(.013)	.198 (.184)	−.013*(.007)	−.354***(.139)
Rents of natural resources	.078(.034)	.050***(.017)	.003 (.011)	−.048* (.031)	.026**(.014)	2.086***(.847)
Foreign direct investment	−.003(.014)	−.070***(.026)	−.001 (.002)	−.012 (.010)	−.005*(.003)	−.666***(.279)
Agriculture, value added	.033***(.028)	−.125***(.022)	−.002 (.011)	−.929 (.796)	.015 (.041)	−.073 (.093)
Industry, value added	−.099(.047)	−.081***(.021)	−.001 (.018)	−.005 (.009)	−.049***(.018)	−4.587***(1.850)
Trade	−.001(.002)	−.005***(.002)	−.007***(.001)	−.006***(.001)	−.006***(.001)	−.002 (.002)
Population density	.003***(.000)	−.005***(.001)	.001 (.002)	−.019 (.016)	−.002 (.003)	.008***(.003)
$\hat{v}_{Industry,\text{ v.a.}}$	.072(.091)	.062 (.024)	.005 (.018)	−.006 (.014)	.032*(.018)	4.581*** (1.854)
$\hat{v}_{Agriculture,\text{ v.a.}}$	−.060***(.037)	.026*(.023)	−.019**(.008)	.909* (.5662)	.008 (.040)	.058(.094)
$\hat{v}_{GDP\text{ p.c.}}$	.488**(.203)	.452 (.112)	.012 (.072)	−.039 (.111)	.312***(.092)	.567***(.244)
Number of obs.	239	131	209	226	411	420
AIC Criterion	2479.3	1325.3	2157.8	1883.5	4093.1	4442.1
Log Likelihood	-1222.669	-645.642	-1061.888	-924.730	-2029.531	-2204.054

Notes: Dependent variable is the counts of threatened animal species. Robust standard errors in brackets. Unbalanced panel data, with n=179 and T=7. "***", "**" and "*" respectively stand for significance level at 1, 5 and 10%. Regarding the overdispersion test, the null hypothesis is equidispersion in Poisson GLMs against the alternative of overdispersion and/or under-dispersion.

Table 5: Plant species: Estimation of negative binomial models

Covariates / Models	Africa	America	Asia	Europe	High-income	Low-income
Intercept	8.88(5.855)	62.23***(13.09)	−21.42**(11.76)	123.69***(27.407)	−125.90***(57.69)	−27.83**(11.80)
lnGDP per capita	−3.890***(1.337)	−9.675***(2.785)	6.214***(2.411)	−11.827***(3.714)	24.69***(11.96)	3.504*(2.200)
Squared lnGDP per capita	.239***(.078)	.364**(.147)	−.403***(.123)	.590***(.183)	−1.210***(.559)	−.283**(.128)
Total plant species	.010***(.001)	.003***(.000)	.002**(.001)	−.021***(.008)	.005***(.001)	.003 (.005)
Climate zone	.176***(.077)	.069**(.027)	−.033**(.017)	−.803***(.191)	−.027 (.035)	.018 (.124)
Forest area	.061***(.016)	.033**(.013)	.036***(.003)	−.210***(.050)	.011*(.006)	.012 (.047)
Mean years of schooling	−.126***(.047)	−.099***(.031)	.014 (.027)	.287***(.097)	.038 (.081)	−.118**(.046)
Rents of natural resources	.033 (.062)	−.005 (.037)	.032 (.024)	−.188***(.038)	−.032 (.197)	−.297*(.198)
Foreign direct investment	.000 (.023)	.028 (.055)	−.002 (.016)	−.034***(.012)	.007 (.030)	.111*(.071)
Agriculture, value added	.174***(.037)	−.118*(.062)	.047 (.046)	−2.385***(.558)	.638 (.523)	.389**(.149)
Industry, value added	−.008 (.085)	−.020 (.048)	−.011 (.039)	.044 (.029)	.043 (.278)	.578**(.411)
Trade	−.001 (.003)	−.010**(.004)	−.001 (.004)	−.016***(.002)	−.016**(.008)	−.004 (.003)
Population density	.006***(.001)	−.000 (.002)	−.000 (.001)	−.050 (.013)	.003 (.003)	.003***(.001)
$\hat{v}_{Industry,\text{ v.a.}}$	.030 (.091)	.004 (.054)	.008 (.038)	.017***(.029)	−.063***(.252)	−.565 (.405)
$\hat{v}_{Agriculture,\text{v.a.}}$	−.164***(.037)	−.120**(.064)	−.186***(.042)	2.201***(.568)	−.702***(.464)	−.404***(.148)
$\hat{v}_{GDP\text{ p.c.}}$	.424**(.203)	.736***(.373)	−.545** (.219)	.726 (.276)	.198***(.387)	1.236***(.337)
Number of obs.	239	131	206	222	408	418
AIC Criterion	1996.5	1315.8	1730.3	958.87	2969	3639.3
Log Likelihood	-981.252	-640.876	-848.159	-462.433	-1467.4805	-1802.632

Notes: Dependent variable is the counts of threatened plant species. Robust standard errors in brackets. See Table 4 for further comments.

• High-income countries: An inverted U-shaped relationship appears between income per capita and threatened species, supporting a possible harmonious cohabitation between biological species and human economic activities during the development process. The more species-rich the countries are, the more threatened species they hold. Similarly, the more forest covered high-income countries are, the more threatened plant species they sheltered contrarily to animal species. Except for natural resources rents which harm animal species, agriculture, industry, trade and population density are found not to be conflicting with both animal and plant species.

• Low-income countries: Focusing on threatened animal species, our results signal a U-curve implying that more animal species are threatened by extinction during the process of economic development, conversely to plant species where an inverted U-shape is observed between the number of threatened species and income per capita. Large forest cover and animal species richness are associated to increasing threatened animal species. Furthermore, our results indicate that human population conflicts with biological species by increasing the number of threatened animal and plant species, whereas industrial and agricultural production harm only plant species.

This regional analysis of the drivers of biological species loss by continent has pointed out some interesting regional heterogeneities. For instance, human population measured by population density and agricultural economic production conflict with both our indicators of biological diversity loss in Africa while in America natural resources exploitation harms animal species. Focusing on whether there is a harmonious cohabitation between economic activities and animal and plant species, our results indicate for both species group a U-shaped curve in income per capita in Africa and America. Such a result implies the existence of a conflicting relationship between biodiversity and human activities in these two regions. Further, the development level analysis distinguishing high and low-income countries delivers results that strengthen those of our non-parametric analysis.[11] For both species group, high-income countries are globally found to be threatening fewer species, supporting conclusions regarding a peaceful cohabitation between animal and plant species and economic activities.

[11] High income countries are those showing an lnGDP per capita higher than the sample mean, 9.1 $.

5. Concluding remarks

The existing literature on the sources of biodiversity loss strongly underlines conflicts between livings species, a competitive exclusion. In relation to economic and population growth, this implies that human society and economic activities grow at the expense of non-human species, thus biodiversity.[12] In accordance with this assumption, this paper contributes to the empirical literature on the economic causes of biodiversity loss by investigating whether a cohabitation between animal and plant species and human activities is possible.

By applying count data regression techniques, we find that income per capita significantly affects the number of species at threat. More concretely, our results suggest that the link of our indicator of biodiversity loss to income is not linear but rather depicts a seemingly inverted U-shape, globally implying that species loss tends to slow that with the level of economic development. Such a conclusion is supported by results obtained while distinguishing high and low-income countries. Considering uniquely low-income countries, our regression analysis suggests that GDP per capita increases the number of animal species threatened by extinction. These results can be linked to the patterns in the Living Planet Index (LPI) between 1970 and 2010. In tropical climate zones, where developing countries mostly lie, a rapidly decreasing trend in LPI is to observe contrarily to temperate climate countries where an upward trend is noticed. Furthermore, a global-level investigation uniquely focused on the functional form of the relationship between both factors, namely income per capita and the number of threatened species, helps see that biodiversity is degraded in developing countries while fewer species are at threat in high-income countries. Besides income which depicts an inverted U-shaped relationship to threatened species, human population growth and agricultural production globally conflict with animal and plant species. Overall in developed countries, where lower agricultural share in GDP and population growth are observed, a peaceful cohabitation with biological species is possible.

This study on biodiversity loss can be extended in several ways. A possible extension of this paper could be on the role of deforestation and forest exploitation in endangering biodiversity in tropical countries. These possible improvements are left to future researches. Furthermore, this study can be deepen considering several other indicators of biodiversity loss.

[12] The concept is actually known as *Gause's law* and can be found in Czech (2004, 2008).

References

[1] Rafat Alam and Nguyen Van Quyen. International trade and its impact on biological diversity. In Andreas Kontoleon, Unai Pascual, and TimothyEditors Swanson, editors, *Biodiversity Economics: Principles, Methods and Applications*, pages 246–268. Cambridge University Press, 2007.

[2] Francis J Anscombe. The transformation of Poisson, binomial and negative-binomial data. *Biometrika*, 35 (3/4):246–254, 1948.

[3] John Asafu-Adjaye. Biodiversity loss and economic growth: A cross-country analysis. *Contemporary Economic Policy*, 21(2):173–185, 2003.

[4] Millennium Ecosystem Assessment. Ecosystems and human well-being: Wetlands and water. *World resources institute, Washington, DC*, 5, 2005.

[5] Theophile Azomahou, Francois Laisney, and Phu Nguyen-Van. Economic development and CO2 emissions: A nonparametric panel approach. *Journal of Public Economics*, 90(6):1347–1363, 2006.

[6] Théophile T Azomahou, Micheline Goedhuys, and Phu Nguyen-Van. A structural nonparametric reappraisal of the co2 emissions–income relationship. *Revue Economique*, 67(1):167–174, 2016.

[7] Bartosz Bartkowski, Nele Lienhoop, and Bernd Hansjürgens. Capturing the complexity of biodiversity: A critical review of economic valuation studies of biological diversity. *Ecological Economics*, 113:1–14, 2015.

[8] RJH Beverton and SJ Holt. On the dynamics of exploited fish populations. *Ministry of Agriculture, Fisheries and Food (Series 2, Fyshery Investigations*, 19, 1957.

[9] James A Brander and M Scott Taylor. The simple economics of easter island: A Ricardo-Malthus model of renewable resource use. *American Economic Review*, 88(1):119–138, 1998.

[10] William A Brock and M Scott Taylor. The green Solow model. *Journal of Economic Growth*, 15(2):127–153, 2010.

[11] Glen G Brown, William A Maher, Richard H Norris, and J Mathieu. Nature's limits. In *Starke, L.(Ed.), State of the World.* Citeseer, 1995.

[12] Lawrence D Brown, T Tony Cai, and Harrison H Zhou. Nonparametric regression in exponential families. *The Annals of Statistics*, 38(4):2005–2046, 2010.

[13] Francisco Cabo. Valuation of biodiversity within a North–South trade model. *Environment and Development Economics*, 4(03):251–277, 1999.

[14] A Colin Cameron and Pravin K Trivedi. Regression-based tests for overdispersion in the poisson model. *Journal of Econometrics*, 46(3):347–364, 1990.

[15] A Colin Cameron and Pravin K Trivedi. *Regression Analysis of Count Data.* Cambridge University Press, 2013.

[16] Ann Carlos and Frank Lewis. Property rights, competition and depletion in the eighteenth-century canadian fur trade: The role of the european market. *Canadian Journal of Economics*, 32(3):705–728, 1999.

[17] Yi-Bin Chiu. Deforestation and the environmental Kuznets curve in developing countries: A panel smooth transition regression approach. *Canadian Journal of Agricultural Economics*, 60(2):177–194, 2012.

[18] Colin W Clark. The economics of overexploitation. *Science*, 181(4100):630–634, 1973.

[19] Colin W Clark. Profit maximization and the extinction of animal species. *Journal of Political Economy*, 81 (4):950–961, 1973.

[20] Colin W Clark. Mathematical bioeconomics. In *Mathematical Problems in Biology*, pages 29–45. Springer, 1974.

[21] B.R Copeland and A Kotwal. Water use and economic growth: Reconsidering the environmental Kuznets curve relationship. *European Economic Review*, 40:1745–1760, 1996.

[22] Ross B Cunningham and David B Lindenmayer. Modeling count data of rare species: Some statistical issues. *Ecology*, 86(5):1135–1142, 2005.

[23] Brian Czech. Prospects for reconciling the conflict between economic growth and biodiversity conservation with technological progress. *Conservation Biology*, 22(6):1389–1398, 2008.

[24] Partha Dasgupta. Nature's role in sustaining economic development. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 365(1537):5–11, 2010.

[25] Sandra Díaz, Joseph Fargione, F Stuart Chapin III, and David Tilman. Biodiversity loss threatens human well-being. *PLoS Biol*, 4(8):e277, 2006.

[26] Simon Dietz and W Neil Adger. Economic growth, biodiversity loss and conservation effort. *Journal of Environmental Management*, 68(1):23–35, 2003.

[27] Florian V Eppink and Jeroen CJM Van Den Bergh. Ecological theories and indicators in economic models of biodiversity loss and conservation: A critical review. *Ecological Economics*, 61(2):284–293, 2007.

[28] Scott Farrow. Extinction and market forces: Two case studies. *Ecological Economics*, 13(2):115–123, 1995.

[29] Andreas Freytag, Christoph Vietze, and Wolfgang Völkl. What drives biodiversity? An empirical assessment of the relation between biodiversity and the economy. *International Journal of Ecological Economics and Statistics*, 24(1):1–16, 2012.

[30] Marcelino Fuentes. Economic growth and biodiversity. *Biodiversity and Conservation*, 20(14):3453–3458, 2011.

[31] H Scott Gordon. The economic theory of a common-property resource: The fishery. In *Classic Papers in Natural Resource Economics*, pages 178–203. Springer, 1954.

[32] Gene M Grossman and Alan B Krueger. Economic growth and the environment. *The Quarterly Journal of Economics*, 110(2):353–377, 1995.

[33] George Emm Halkos and Nickolaos G Tzeremes. Measuring biodiversity performance: A conditional efficiency measurement approach. *Environmental Modelling & Software*, 25(12):1866–1873, 2010.

[34] Wolfgang Härdle and Oliver Linton. Applied nonparametric methods. *Handbook of Econometrics*, 4:2295–2339, 1994.

[35] Joseph M Hilbe. *Negative binomial regression*. Cambridge University Press, 2011.

[36] John P Hoffmann. Social and environmental influences on endangered species: A cross-national study. *Sociological Perspectives*, 47(1):79–107, 2004.

[37] MH Hoyle. Transformations: An introduction and a bibliography. *International Statistical Review/Revue Internationale de Statistique*, pages 203–223, 1973.

[38] David Huang and Chae W Lee. Toward a general model of fishery production. *Southern Economic Journal*, 43(1), 1976.

[39] A Andrew John and Rowena A Pecchenino. International and intergenerational environmental externalities. *The Scandinavian Journal of Economics*, 99(3):371–387, 1997.

[40] David Katz. Water use and economic growth: Reconsidering the environmental Kuznets curve relationship. *Journal of Cleaner Production*, 88:205–213, 2015.

[41] Jeremy T Kerr and David J Currie. Effects of human activity on global extinction risk. *Conservation Biology*, 9(6):1528–1538, 1995.

[42] Andreas Kontoleon, Timothy Swanson, and Unai Pascual. *Biodiversity Economics: Principles, Methods and Applications*. Cambridge University Press, 2007.

[43] Gary Koop and Lise Tole. Is there an environmental Kuznets curve for deforestation? *Journal of Development Economics*, 58(1):231–244, 1999.

[44] Dayton M Lambert, Jason P Brown, and Raymond JGM Florax. A two-step estimator for a spatial lag model of counts: Theory, small sample performance and an application. *Regional Science and Urban Economics*, 40 (4):241–252, 2010.

[45] Bruno Lanz, Simon Dietz, and Tim Swanson. The expansion of modern agriculture and global biodiversity decline: An integrated assessment. *Ecological Economics*, 144:260 – 277, 2018.

[46] Qi Li and Jeffrey Scott Racine. *Nonparametric Econometric Methods*. Emerald Group Publishing, 2009.

[47] Pallab Majumder, Robert P Berrens, and Alok K Bohara. Is there an environmental Kuznets curve for the risk of biodiversity loss? *The Journal of Developing Areas*, 39(2):175–190, 2006.

[48] Julianne H Mills and Thomas A Waite. Economic prosperity, biodiversity conservation, and the environmental Kuznets curve. *Ecological Economics*, 68(7):2087–2095, 2009.

[49] Robin Naidoo and Wiktor L Adamowicz. Effects of economic prosperity on numbers of threatened species. *Conservation Biology*, 15(4):1021–1029, 2001.

[50] Paulo ALD Nunes and Jeroen CJM van den Bergh. Economic valuation of biodiversity: Sense or nonsense? *Ecological Economics*, 39(2):203–222, 2001.

[51] Theodore Panayotou. Economic growth and the environment. *CID, Harvard University, Working Paper*, 2000.

[52] C Perrings and G Halkos. Biodiversity loss and income growth in poor countries: The evidence. Technical report, ecoServices Working Paper, ASU, Tempe, 2010.

[53] Charles Perrings. The economics of biodiversity: The evolving agenda. *Environment and Development Economics*, 15(06):721–746, 2010.

[54] Ester Polaina, Manuela González-Suárez, and Eloy Revilla. Socioeconomic correlates of global mammalian conservation status. *Ecosphere*, 6(9):146, 2015.

[55] Stephen Polasky, Christopher Costello, and Andrew Solow. The economics of biodiversity. *Handbook of Environmental Economics*, 3:1517–1560, 2005.

[56] Jonas Ngouhouo Poufoun, Jens Abildtrup, Dénis Jean Sonwa, and Philippe Delacote. The value of endangered forest elephants to local communities in a transboundary conservation landscape. *Ecological Economics*, 126: 70–86, 2016.

[57] Jeffrey Scott Racine. *Nonparametric Econometrics: A primer*. Now Publishers Inc, 2008.

[58] Sherwin Rosen, Kevin M Murphy, and Jose A Scheinkman. Cattle cycles. *Journal of Political Economy*, 102 (3):468–492, 1994.

[59] Milner B Schaefer. Some considerations of population dynamics and economics in relation to the management of the commercial marine fisheries. *Journal of the Fisheries Board of Canada*, 14(5):669–681, 1957.

[60] Vernon Smith. The primitive hunter culture, pleistocene extinction, and the rise of agriculture. *Journal of Political Economy*, 83(4):727–55, 1975.

[61] Vernon L Smith. Economic principles in the emergence of humankind. *Economic Inquiry*, 30(1):1–13, 1992.

[62] Scott M Taylor. Buffalo hunt: International trade and the virtual extinction of the North American bison. *The American Economic Review*, 101(7):3162–3195, 2011.

[63] Clem Tisdell. Biodiversity conservation, loss of natural capital and interest rates. *Ecological Economics*, 70 (12):2511–2515, 2011.

[64] Jana Verboom, Rob Alkemade, Jan Klijn, Marc J Metzger, and Rien Reijnen. Combining biodiversity modeling with political and economic development scenarios for 25 EU-countries. *Ecological Economics*, 62(2):267–276, 2007.

[65] Jennie Wienke. The impact of economic development on plant diversity: A test of the environmental Kuznets curve. In *2015 Fall Conference: The Golden Age of Evidence-Based Policy*. Appam, 2015.

[66] Rainer Winkelmann. *Econometric Analysis of Count Data*. Springer Science & Business Media, 2008.

[67] Jeffrey M Wooldridge. Quasi-maximum likelihood estimation and testing for nonlinear models with endogenous explanatory variables. *Journal of Econometrics*, 182(1):226–234, 2014.

[68] Jeffrey M Wooldridge. Control function methods in applied econometrics. *Journal of Human Resources*, 50 (2):420–445, 2015.

[69] Jeffrey M Wooldridge. *Introductory econometrics: A modern approach*. Nelson Education, 2015.

List of countries of our dataset

Afghanistan, Albania, Algeria, American Samoa, Angola, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, The Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Cabo Verde, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Djibouti, Dominica, Dominican Republic, Ecuador, Egypt Arab Rep., El Salvador, Equatorial Guinea, Estonia, Ethiopia, Fiji, Finland, France, Gabon, Gambia The, Georgia, Germany, Ghana, Greece, Grenada, Guatemala, Guinea, Guinea-Bissau, Haiti, Honduras, Hong Kong SAR, China, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Korea, Rep., Kuwait, Kyrgyz Republic, Laos, Latvia, Lebanon, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Macao, Macedonia FYR, Madagascar, Malawi, Malaysia, Maldives, Mali, Marshall Islands, Mauritania, Mauritius, Mexico, Micronesia Fed. Sts., Moldova, Mongolia, Montenegro, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russian Federation, Rwanda, Samoa, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Slovak Republic, Slovenia, Solomon Islands, Somalia, South Africa, Spain, Sri Lanka, Sudan, Suriname, Swaziland, Sweden, Switzerland, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Tuvalu, Uganda, Ukraine, United Kingdom, United States, Uruguay, Uzbekistan, Vanuatu, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.